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INSECTICIDE TESTS FOR CONTROL OF THE SOUTHERN CORN ROOTWORM IN PEANUTS 1/

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Each year the peanut crop in the Virginia-North Carolina commercial peanut-growing region is attacked by the southern corn rootworm (Diabrotica undecimpunctata howardi Barber). This injury has become more severe in the last few years, perhaps owing in part to a succession of wet growing seasons. On heavy, poorly drained land such injury may run as high as 80 percent of the total yield of the field-cured peanuts. The larva causes the damage by cutting through the shell of the pod and feeding on the kernels. Even where little feeding occurs, the openings made in the pods permit the entrance of moisture and soil microorganisms, which cause decay or deterioration of the kernels. Many of the pistils, or "needles," may also be attacked soon after they enter the ground and thus be prevented from producing nuts.

Fink (2) was the first to report injury to peanuts by the southern corn rootworm. More recently Miller (4) stated that in Virginia this rootworm was the most important underground insect pest of peanuts. Grayson and Poos (3) found that an application to the soil of 25, 50, or 100 pounds of DDT per acre gave reductions of 47 to 84 percent in numbers of pods injured by this insect. They also found in one small test that three applications of a 0.66-percent DDT spray to the peanut foliage reduced the infestation by 52 percent. Tests by Dobbins and Fronk (1) at Holland, Va., showed that 25 pounds of DDT or sufficient technical benzene hexachloride to give 0.5 pound of the gamma isomer per acre mixed into the top 2 inches of soil significantly reduced the amount of injury to the pods, but that effective control required a minimum of 1 pound of the gamma isomer or 100 pounds of DDT per acre.

Significant reduction in pod injury was also achieved at Beltsville, Md., by treating peanut foliage on June 12, 18 (followed immediately by heavy rain), 20, and 30 with emulsions containing 0.1 percent of the gamma isomer of benzene hexachloride, 0.1 percent of chlordane, or 4 percent of DDT. The use of water sprays containing 0.05 percent of parathion or 0.1 percent of toxaphene in the form of wettable powders gave negligible control.

1/ Investigations conducted cooperatively by the Virginia Agricultural Experiment Station and the Bureau of Entomology and Plant Quarantine.

2/ The authors are indebted to E. T. Batten, in charge of the Tide-water Field Station of the Virginia Agricultural Experiment Station, at Holland, Va., for invaluable cooperation in these studies.

This paper presents the results of tests of insecticides applied to the soil or to the foliage in small plots of peanuts at Holland, Va., and Beltsville, Md., during 1948 for the control of the southern corn rootworm. Although effective control was obtained with some of the insecticides used in these tests, further trials on a field basis and additional information on the best formulations and dosages to use, the best time to apply them, and possible residue hazards are necessary before these materials can be safely recommended.

All formulations of benzene hexachloride referred to in this paper were made from the technical material, although concentrations and dosages are given in terms of the active, or gamma, isomer. All samples collected for determining residues of insecticides were air-dried unless otherwise indicated.

Applications to the Soil

Two series of plot tests were conducted on Virginia Jumbo peanuts at Holland. DDT and benzene hexachloride dusts were broadcast by hand over the soil and raked into the upper 1-2 inches with a garden rake. The dosage of the active ingredient for each plot was diluted with pyrophyllite to make 4 pounds of dust. The dust was placed in paper bags (two 2-pound lots) in order to facilitate distributing the materials uniformly over the plots. Each plot contained 6 rows and was 1 square rod in area. Each treatment was replicated five times in a Latin square. Applications were made on June 3 in one series and on July 7-8 in the other to peanuts planted on May 24. Plants were dug from each plot on September 8 for estimating the damage to the pods. The results are summarized in table 1.

Table 1.—Effect of benzene hexachloride and DDT dusts applied to the soil on the injury to developing peanut pods by southern corn rootworm larvae. Holland, Va.

Dust	: Active :		: Pods penetrated	
	: ingre- :		: by rootworm	
	: dient : June 3 : July 7		: June 3 : July 7	
	: per acre: treatments: treatments:		: treatments: treatments	
	<u>Pounds</u>	<u>Percent</u>	<u>Percent</u>	<u>Percent</u>
Untreated checks		86	84	78 68
Benzene hexachloride				
(gamma isomer)	0.5	25	36	16 25
	1	8	28	4 20
	1.5	7	21	3 13
DDT	100 ^{1/}	18	42	10 29
Difference required for significance:				
At 5-percent level		9	14	
At 1-percent level		13	20	

^{1/} Only 67 pounds applied June 3.

Preliminary data were also obtained on the effectiveness of parathion, toxaphene, and chlordane in comparison with benzene hexachloride against the southern corn rootworm. The applications were made on June 3 in one series and on July 8 in another. Each treatment was duplicated on each date. An estimate of larval injury was taken on September 7-8. The results are summarized in table 2.

Table 2.—Preliminary tests with parathion, toxaphene, chlordane, and benzene hexachloride dusts in the soil to control injury to peanut pods by southern corn rootworm. Holland, Va.

Dust	: Active	Injured pods	
	: ingredient	: June 3	: July 8
	: per acre	: treatments	: treatments
	<u>Pounds</u>	<u>Percent</u>	<u>Percent</u>
Untreated checks		61	76
Benzene hexachloride (gamma isomer)	1	7	9
Parathion	2	36	40
	5	10	22
	10	2	12
Toxaphene	20	21	34
	40	5	22
Chlordane	10	29	25
Difference required for significance:			
At 5-percent level		21	25
At 1-percent level		31	37

These results, considered with those shown in table 1, indicate that the June applications of all the insecticides were more effective than the July applications. All treatments significantly reduced the amount of pod injury. The treatments with benzene hexachloride at 1 and 1.5 pounds of the gamma isomer, with 5 and 10 pounds of parathion, and with 40 pounds of toxaphene per acre were the best and approximately equal in effectiveness. Since 1 pound of the gamma isomer of benzene hexachloride or 5 pounds of parathion gave very effective control, it is probable that 0.75 pound of the gamma isomer or 4 pounds of parathion per acre may give satisfactory control if the application is made at the right time.

To obtain yield samples, the plants in the two inside rows of each plot were dug, bundled, and artificially dried. The peanuts were picked from these samples by means of a mechanical picker and weighed. The results are summarized in table 3. Of the treatments applied on June 3, the following gave significant increases in yield: Benzene hexachloride at 1 and 1.5 pounds of the gamma isomer, parathion at 5 pounds, toxaphene at 40 pounds, and DDT at 67 pounds to the acre. All the July treatments except parathion at 2 pounds to the acre gave considerable increases in yield.

Table 3.- Yields of field-cured peanuts from plots receiving various soil treatments to control southern corn rootworm larvae. Holland, Va.

Dust	: June 3 treatment		: July 7-8 treatment	
	: Active	: Average	: Increase	: Average
	: ingredient	: yield per	: over	: yield per
	: per acre	: 0.33 sq.rd.	: check	: 0.33 sq.rd.
	<u>Pounds</u>	<u>Ounces</u>	<u>Percent</u>	<u>Ounces</u>
Untreated checks		58		49
DDT	100 <u>1/</u>	80	37	68
Benzene hexachloride (gamma isomer)	0.5	74	27	68
	1	83	42	69
	1.5	86	48	66
Difference required for significance at 5-percent level		17		<u>2/</u>
Untreated checks		58		41
Parathion	2	63	9	61
	5	91	57	85
	10	61	5	76
Chlordane	10	71	22	96
Toxaphene	20	71	22	75
	40	110	89	85
Benzene hexachloride (gamma isomer)	1	96	65	87
Difference required for significance at 5-percent level		<u>3/</u>		29

1/ Only 67 pounds applied June 3.

2/ F value 1.94 not significant, tabular F 3.26.

3/ F value 3.18 approaches significance, tabular F 3.79.

Applications to the Foliage

At Beltsville.— Plots of peanuts that had the foliage treated three times with an insecticide to control the tobacco thrips (Frankliniella fusca (Hinds)) were also examined for injury by the southern corn rootworm. The applications were made on June 25, July 2, and July 12. Two experiments were conducted for the purpose of comparing the effectiveness of various formulations, one with emulsions (five replications of each treatment) and a second with dust formulations (six replications of each treatment). In the second experiment parathion emulsion was substituted for chlordane dust, which failed to arrive as planned. The emulsion sprays were applied by means of a knapsack sprayer fitted with a Monarch-type oil-burner nozzle, and the dust mixtures were applied with a rotary hand duster. To control a heavy infestation of potato leafhoppers, all plots were treated on July 26 and August 2 and 13 with a 1-percent impregnated DDT-sulfur dust. Estimates of southern corn rootworm injury to the pods were made on September 14-15 and are summarized in table 4.

Table 4.—Effect of three applications of insecticides to peanut foliage on the injury to peanut pods by southern corn rootworm larvae. Beltsville, Md.

Formulation	: Approximate :		
	: total active : <u>Injured pods</u>		
	: ingredient :		
	: per acre	: Average	: Range
	<u>Pounds</u>	<u>Percent</u>	<u>Percent</u>
<u>Experiment 1</u>			
Untreated checks		66	58 - 76
Benzene hexachloride, 0.5-percent (gamma isomer) emulsion	1.1	25	9 - 41
Toxaphene, 0.75-percent emulsion	1.7	58	47 - 70
DDT, 2-percent emulsion	4.6	53	43 - 65
Chlordane, 0.5-percent emulsion	1.1	30	4 - 54
Difference required for significance:			
At 5-percent level		20	
At 1-percent level		27	
<u>Experiment 2</u>			
Untreated checks		44	15 - 65
Impregnated DDT-sulfur, 1-percent dust	0.7	45	11 - 76
Parathion, 1-percent dust	.7	26	8 - 52
Benzene hexachloride, 1-percent (gamma isomer) dust	.7	4	2 - 9
Toxaphene, 10-percent dust	6.9	10	0 - 22
Parathion, 0.2-percent emulsion	.45	41	13 - 59
Difference required for significance:			
At 5-percent level		17	
At 1-percent level		23	

In these tests emulsions containing 2 percent of DDT or 0.75 percent of toxaphene were of little value in controlling the southern corn rootworm. Emulsions containing 0.5 percent of the gamma isomer of benzene hexachloride or 0.5 percent of chlordane gave significant control. The control obtained with dusts containing 1 percent of the gamma isomer or 10 percent of toxaphene was comparable to that obtained at Holland with the most effective soil treatment. However, the infestation at Holland was considerably heavier than that at Beltsville. With parathion the 1-percent dust gave some control, but the 0.2-percent emulsion was ineffective. DDT applied to the foliage either as a 1-percent dust or as a 2-percent emulsion gave no control of this insect. The excellent results obtained with dusts containing 10 percent of toxaphene and 1 percent of the gamma isomer were unexpected in view of the heavy rainfall at Beltsville during the 1948 growing season. Here again the much lower infestation by this insect at Beltsville must be taken into consideration.

At Holland.- Experiments were conducted on square-rod plots of Virginia Jumbo peanuts to test the efficiency of several insecticides in controlling the southern corn rootworm by means of applications to the foliage. Each treatment was replicated five times. Seven applications were made to each plot at intervals of approximately 2 weeks from June 19 to August 23. The large number of applications were made in order to obtain maximum control. The dust mixtures were applied with a rotary hand duster, the emulsions with a knapsack sprayer equipped with a Monarch-type oil-burner nozzle, and the wettable-powder formulations with a knapsack sprayer equipped with a Mohawk nozzle. On September 13 plants were dug from each plot for estimating the damage to the pods, and on October 18 the plants in the two inside rows from each plot were dug for yield determinations. The results are summarized in table 5.

All the dust treatments gave significant control, but benzene hexachloride gave much better control than any of the others. Among the sprays, benzene hexachloride at 0.5 percent of the gamma isomer, 0.5 and 1 percent of chlordane, and 0.5 percent of toxaphene gave significant control. Again the benzene hexachloride was significantly better than any of the other treatments.

Tests for Harmful Residue^{3/}

DDT.- Trials by Dobbins and Fronk (1948) and Grayson and Poos (1947) had shown that applications of DDT to peanut foliage gave little promise of practical control of the southern corn rootworm. During 1948, therefore, DDT was tested only by applications to the soil for comparison with results obtained during previous years. Since it was thought at the time that it was not absorbed by plants, no samples of foliage or nuts were taken from the treated plots for chemical analysis to determine whether or not they contained any DDT.

Benzene Hexachloride.- Analyses of several samples of field-cured peanuts (in the shell) from plots in which benzene hexachloride had been used as a soil insecticide at the rates of 0.5, 1, or 1.5 pounds of the gamma isomer per acre gave somewhat erratic results. Twelve additional samples of shelled peanuts that had been grown on plots that had received 1 or 1.5 pounds of the gamma isomer per acre, also applied to the soil, either on June 3 or July 7, were reported to have a benzene hexachloride

^{3/} The Division of Insecticide Investigations made all the chemical analyses mentioned in this paper.

Table 5.--Infestation and yields of field-cured peanuts from plots having the foliage treated seven times, June 19-August 23, with various insecticides to control the southern corn rootworm. Holland, Va.¹

Insecticide	: Approximate :			: Infested :			Yield
	: total active	: ingredient	: per acre	: pods	: per acre	: per acre	
	<u>Pounds</u>	<u>Percent</u>	<u>Pounds</u>	<u>Percent</u>	<u>Pounds</u>		
<u>Dusts</u>							
Untreated checks							
Benzene hexachloride, 1-percent gamma isomer	1.05	71				1955	
2-percent gamma isomer	1.82	10				2526	
Parathion, 0.5 percent	0.49	7				2250	
1 percent	1.05	59				2460	
2 percent	2.17	60				2310	
Chlordane, 5 percent	4.62	50				2124	
10 percent	9.80	43				2360	
Toxaphene, 10 percent	13.37	11				2430	
20 percent	19.67	10				2082	
Difference required for significance at 5-percent level		31				2400	
		9					
<u>Sprays</u>							
Untreated checks							
Benzene hexachloride emulsion, 0.5 percent	0.049	78				1955	
gamma isomer		25				2576	
Chlordane emulsion, 1 percent	.098	62				2576	
0.5 percent	.049	39				2082	
0.1 percent	.007	76				2028	
Toxaphene suspension, 0.5 percent	.084	70				2028	
0.1 percent	.014	74				2286	
Difference required for significance at 5-percent level		6					

¹/Boyd Harsnberger, Virginia Agricultural Experiment Station, made the statistical analysis of these data.

content of less than 1 p.p.m., if any. Samples of foliage taken on October 18 from plots that had received seven applications of benzene hexachloride dust containing 2 percent of the gamma isomer or of a spray containing 0.5 percent of the gamma isomer during the period June 19 to August 23 showed no organic chlorine. Samples of shelled peanuts harvested on October 20 from the plots that had been sprayed seven times with 0.5, 1, or 2 percent of the gamma isomer were also reported to contain less than 1 p.p.m., if any, of benzene hexachloride.

Chlordane.-- The analyses of samples of field-cured peanuts (in the shell) grown on plots to which 10 pounds of chlordane had been applied to the soil either on June 3 or on July 8 showed no residue. Additional analyses of shelled peanuts from the same plots confirmed these results. Peanut foliage taken on October 6 from plots that had received applications of a 0.5-percent emulsion on June 25 and July 2 and 12, and of 1-percent DDT-impregnated sulfur dust (a total of about 70 pounds per acre) on July 26 and August 2 and 13 showed 3 p.p.m. of organic chlorine. Samples of foliage taken on October 18 from plots that had received seven applications of 10-percent chlordane dust or 0.5-percent chlordane emulsion during the period June 19 to August 23 contained, respectively, 7.7 and 8.6 p.p.m. of organic chlorine.

Parathion.-- Less than 0.1 p.p.m., if any, parathion was reported from analyses of unshelled peanuts taken on October 20 from plots to which 2, 5, or 10 pounds of parathion had been applied to the soil either on June 3 or on July 8. Samples of peanut foliage taken in October, and air-dried, from plots to which parathion had been applied to foliage as indicated below, were analyzed without finding any evidence of parathion.

<u>Formulation</u>	<u>Time of application</u>	<u>Pounds of parathion per acre-application</u>
1-percent dust	June 3, 15, and 23	0.25
	June 25, July 2 and 12	.23
0.2-percent emulsion	Same	.15
2-percent dust	7 times from June 19 to Aug. 23	.31

Toxaphene.-- The analyses of samples of field-cured peanuts in the shell that had been grown on plots that received toxaphene at the rate of 20 or 40 pounds per acre on June 3 or July 8 indicated no residue. Analyses of additional samples from these plots, which included shelled nuts, confirmed the previous results. The results of analyses of samples of peanut foliage taken at harvesttime in October from plots to which toxaphene was applied are given below:

(1) Samples from plots that had been treated with a 10-percent dust on June 25 and July 2 and 12 at approximately 2.3 pounds of toxaphene per acre-application, plus a dust containing 1 percent of DDT in sulfur applied on July 26 and August 2 and 13 at approximately 0.23 pound of DDT per acre-application, contained 0.5 p.p.m. of organic chlorine.

(2) No residue was found in samples treated on the same dates as in (1) with an emulsion containing 0.75 percent of toxaphene at approximately 0.57 pound per acre-application.

(3) Samples of forage taken from plots that had received seven applications of 10-percent dust or 0.5-percent suspension at approximately 1.9 and 0.012 pounds per acre-application during the period June 19 to August 23 contained, respectively, 17.5 and 0 p.p.m. of organic chlorine.

Other Observations

The treated peanuts matured earlier than the untreated peanuts. The nuts from the plots treated with benzene hexachloride were of a much better quality than those from the untreated check plots. The benzene hexachloride dusts also seemed to reduce the injury from wilt (Sclerotium rolfsii), which was severe during 1948 in the field in which these tests were conducted. No off-flavor was detectable in the unprocessed nuts grown under the conditions of these tests. Preliminary tests to investigate the effect of benzene hexachloride as a soil treatment on these peanuts after processing gave negative results.

Despite the promising results obtained on small areas, none of the insecticides or methods of application discussed in this paper are recommended for use by growers until more is known about methods and time of application, effect on plant growth in various types of soil, the possibility of undesirable residual effects on peanuts or on crops grown in rotation with peanuts, and the possibility of harmful residues on or in crops eaten by man and animals.

Summary

Losses of field-cured peanuts caused by the southern corn rootworm (Diabrotica undecimpunctata howardi Barber) on heavy, poorly drained land ran as high as 80 percent of the total yield as determined by counts of injured pods. These losses became progressively greater in the Virginia-North Carolina commercial peanut-growing area during the years 1945-1948 than in previous years.

During 1948 significant control was obtained at Holland, Va., with certain organic insecticides broadcast as dusts by hand over the soil of small plots and raked into the upper 1-2 inches. These materials and the dosages per acre were as follows: Technical benzene hexachloride at 1 or 1.5 pound of the gamma isomer; 5 pounds of parathion, 40 pounds of toxaphene, and 67 pounds of DDT. Applications made on June 3 were more effective than those on July 7-8.

Three applications to peanut foliage of emulsions containing technical benzene hexachloride or chlordane, at the rate of approximately 0.38 pound of the active ingredient per acre-application, gave significant control at Beltsville, Md., where the infestation was less severe than in southeastern Virginia. At Beltsville dust mixtures containing technical benzene hexachloride or toxaphene applied at approximately 0.23 and 2.3 pounds of active ingredient per acre-application, respectively, also gave excellent control.

Seven applications of certain formulations were made to the foliage on small plots of peanuts at Holland, Va., during the period June 19 to August 23, in order to obtain maximum control. The following formulations gave significant control: In dust form 1 and 2 percent of the gamma isomer of technical benzene hexachloride, 2 percent of parathion, 5 and 10 percent of chlordane, and 10 and 20 percent of toxaphene; in emulsion form, 0.5 percent of the gamma isomer of benzene hexachloride and 0.5 and 1 percent of chlordane. Benzene hexachloride gave significantly better control than any of the other insecticides.

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